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ARE THE "BATHOLITHS" OF THE HALIBURTON-BANCROFT AREA, ONTARIO, CORRECTLY NAMED?

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The large areas, composed essentially of banded red gneiss, which are found throughout the Haliburton-Bancroft area have been called by Adams and Barlow "batholiths."[1] These appear on maps of this region as circular or oval masses more or less completely surrounded by sediments or schists of sedimentary origin. The stratification of these sediments follows in strike the boundaries of the adjacent gneiss. Moreover, within the gneissic areas are layers of amphibolite or gray gneiss which conform in dip and strike to this same boundary. The gneissic areas, therefore, may be described as domes of red granite gneiss containing gray gneiss and amphibolite in layers striking concentrically to points more or less fixed within the mass and dipping quaquaversally at angles which vary from 37° to 45°.

In his earlier writings, F. D. Adams stated three views as to the origin and method of emplacement of the "Fundamental Gneiss."

> 1. The Fundamental Gneiss may be the remains of a primitive crust which was penetrated by great masses of igneous rocks and subjected to successive dynamic movements. The Grenville series may be an upward continuation of the Fundamental Gneiss under altered conditions, marking a transition from a primitive crust to normal sediments.
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> 2. The Grenville series may be considered as distinct from the Fundamental Gneiss and reposing on it unconformably, being a highly altered series of clastic origin; the Fundamental Gneiss having some such origin as suggested above or being an older intrusive series of still more highly altered sediments.
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> 3. The fundamental Gneiss may be considered as a great mass of eruptive rock which has eaten upward and penetrated the Grenville series, while the

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[1] *Geol. Surv. Can., Mono.,* VI (1910), 12.

> Grenville series represents a series of altered sediments of Laurentian, Huronian, or subsequent age.[1]

Adams in the same article stated that the last hypothesis was untenable.

> The world-wide distribution of the Fundamental Gneiss (forming, as it does, wherever the base of the geological column is exposed to view, the foundation upon which all subsequent rocks are seen to rest) is opposed to this view as is also its persistent gneissic or banded character.[2]

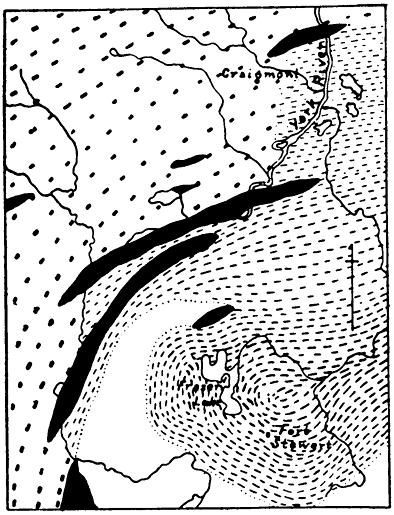

FIG. 1.—Map of the corundum syneite district of Craigmont, Ontario.

Black, limestone; white, amphibolite; dashed, gneissic granite; dotted, gneissic granite with amphibolitic inclusion.

Later, in 1897, Adams altered his earlier view. He writes:

> The batholiths are undoubtedly formed by an uprising of the granitic magma from below, and these foci indicate the axes of greatest upward movement. These centers are not all areas of most rapid uplift, however. On the contrary, the gneissic foliation in some cases dips inward in all directions toward the center, thus marking them as places where the uprise of the magma was impeded, that is to say, places where the overlying strata have sagged down into the granite magma.[3]

A striking fact concerning these so-called batholiths is that they do not cut across the structure of the invaded rocks, a fundamental characteristic by which post-Cambrian batholiths are recognized. While it is true that there are bodies within the district which cut across the structure of the country rock, they are unusual, and concordant relationships are much more common.

A glance at the map (Fig. 1) which shows the corundum syenite district of Craigmont, Ontario, makes clear the concentric arrangement of the sedimentary rocks within the gneiss areas.

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[1] *Journal of Geology*, I (1893), 330–32.

[2] *Op. cit.*, 332.

[3] *Am. Jour. Sci.*, III (1897), 173–80.

The granite was intruded between the layers of limestone. As in the present case, long narrow layers of limestone are often found isolated in the gneiss. These layers are in parallel bands and the strike of their stratification conforms to the strike of the gneissic structure of the surrounding granite.

If the boundary between gneiss and pure limestone is sought, it will invariably be found that there is a transitional contact zone. The distinction between areas which may be designated as "Gneiss with amphibolitic inclusions" or "Amphibolite" or "Limestone invaded by much gneiss" depends upon the degree to which the granite has invaded the limestone and altered it to amphibolite. In general, on crossing the strike from limestone to amphibolite, there is a gradual transformation of one rock into the other. The amphibolite in turn is transitional to red gneiss through the intermediate stage of gray gneiss. Xenoliths of amphibolite within the gneiss are in no degree so abundant as stringers of amphibolite varying from a few centimeters to a meter in diameter and the schistose structure of which conforms to the gneissic structure of the granite and the stratification of the limestone.

Adams[1] attributes the parallel arrangement of these bodies to movements of the granite after intrusion. He conceives that the limestone blocks, stoped from the roof of the batholith, were softened by heat and pulled out into lenses by flowage.

The parallel banding of pre-Cambrian rocks is not a local feature, illustrated only in the rocks of the Haliburton-Bancroft area. It is, rather, characteristic of most pre-Cambrian terranes. The interbanding of gneiss of igneous origin with sediments is shown by Lawson in his study of the Lake of the Woods. Högbom[2] has described similar relationships which are shown by the rocks about Upsala, Sweden.

The gneiss of the pre-Cambrian of the Adirondacks is so mingled with limestone and other sediments that for years it has been a mooted question whether to consider it of igneous or sedimentary origin. It forms lenses and sheets in the sediments, or traverses them so irregularly that an exact interpretation is difficult.

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[1] *Can. Geol. Surv., Memoir No. 6* (1910), 73-78.

[2] *Bull. Geol. Instu., Univ. Upsala,* X (1910-11), 39.

However, C. H. Smyth, Jr.[1] and H. P. Cushing[2] now consider them igneous.

The gneisses of the Highlands of New Jersey may be described in similar language. These are considered by W. S. Bayley[3] and C. N. Fenner[4] to be sediments invaded by granite.

G. M. Dawson writes as follows concerning the Shuswap Terrane of British Columbia:

> The Shuswap rocks proper evidently represent highly metamorphosed sediments with perhaps the addition of contemporaneous bedded volcanic materials. . . . . These bedded materials are, however, associated with a much greater volume of mica-schists and gneisses of more massive appearance, most of which are evidently foliated plutonic rocks, and are often found to pass into unfoliate granites. The association of these different classes of rocks is so close that it may never be possible to separate them on the map over any considerable area. . . . .
>
> A distinct tendency to parallelism of the strata or foliation with adjacent borders of the Cambrian system has been noted in a number of cases. This might imply that the foliation was largely produced at a time later than the Cambrian, but materials of some of the Cambrian rocks show that the Shuswap series must have fully assumed their crystalline character before the Cambrian period. *It seems, therefore, probable that the foliation of the Shuswap rocks may have been produced rather beneath the mere weight of superincumbent strata than by pressure of a tangentical character accompanied by folding.*[5]

R. A. Daly, in a recent report on this same series, states that it has been injected by innumerable sills and laccoliths. He concludes:

> The extraordinary prevalence of sills and other concordant injections is explained by the extreme fissility of the Shuswap sediments and greenstones. This feature is due to static metamorphism.[6]

Two hypotheses are offered, therefore, to explain the parallel banding of pre-Cambrian rocks. In the Haliburton-Bancroft area, Adams conceives that, in the process of intrusion by magmatic stoping, blocks of limestone were torn from the roof of the invading granite batholiths and elongated parallel to the contact of the granite and limestone by movements of the granite as it consolidated.

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[1] *N.Y. State Mus., 41st Ann. Rept.*, II (1899), 469–97.

[2] *Bull. No. 115*, N.Y. State Mus. (1907), 451–531.

[3] *U.S.G.S., Raritan Folio*, No. 191.

[4] *Journal of Geology*, XXII (1914), 594 ff.

[5] *Bull. Geol. Soc. Am.*, XII (1901), 63–64.

[6] Ann. Rept. Dept. Mines, *Can. Geol. Surv.* (1911), 3–12.

Daly believes that static metamorphism produced planes of weakness within the Shuswap series and that sills of granite were intruded along these planes.

Fenner,[1] discussing the method of intrusion of the granites of the New Jersey Highlands, states that in his opinion gaseous emanations from the granite magma penetrated the sedimentary rocks along planes of weakness and prepared the way for the intrusion of granitic fluids. The intrusion of these fluids produced banded gneisses.

It is, of course, entirely possible that intrusion in the Haliburton-Bancroft region took place by magmatic stoping and that this region is not analogous to the others described. The rock types vary within the several areas and there is, necessarily, a corresponding change in the structural relations. The limestones of the Grenville series would undoubtedly be more altered by the metamorphic effects of the granite than the quartzose rocks of the New Jersey Highlands and the Shuswap series.

It seems to the writer, however, that the facts shown by the study of the Glamorgan gneissic area favor the theory of intrusion by parallel penetration along planes of weakness rather than the theory of intrusion by magmatic stoping.

If intrusion took place by magmatic stoping, the following conditions must be postulated. The objections to each of these conditions are noted.

1. The blocks from the roof of the batholith were stoped off and elongated parallel to the contact.	1. Intrusion by magmatic stoping usually produces an irregular molar contact. The igneous rock cuts the sediments. Though the blocks were elongated parallel to the contact, this would not, except by chance, be parallel to the stratification of the sediments, and yet this is the relationship of the banded structure of the rocks of the Haliburton-Bancroft area.

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[1] *Journal of Geology*, XXII (1914), 594 ff.

2. Adams postulates that the elongation of the blocks occurred in the later stages of batholithic intrusion as the granite solidified.	2. It would seem necessary that this should be true; for a hot, fluid magma, if too hot would melt the blocks and incorporate them into a homogeneous magma. If it were too cold it could not elongate them. The necessary conditions for the production of parallel elongation, therefore, is a narrow temperature range within which the blocks remain viscous. This would be found, it would seem, at a more or less constant distance from the molar contact of the intruding batholith with the country rock. As the magma progresses upward, the central heat of the batholith must likewise progress upward and hence the parallel banding of the batholith produced at any stage would be destroyed in a later stage by the complete solution of the blocks into a homogeneous magma. The so-called "batholiths" are in all stages of dissection yet the parallel structure is persistent from center to edge. The structure is not, therefore, a border phenomenon as Adams' theory would demand.
3. The limestone blocks, stoped from the roof of the granite batholith, floated and so were elongated by the movements of the granite parallel to its contact.	3. Daly[1] has shown that limestone blocks at high temperatures are much heavier than fluid granite. Hence these blocks should sink and leave a clear contact which would be progressively attacked by the hot granite magma. This would not give rise to the parallel structure observed. If, however, they floated they would impede the attack of the granite magma at the contact and their solution or partial solution and elongation would cause an enormous loss of heat and render the further upward progress of the batholith very difficult.

It is estimated by Adams and Barlow that 20 per cent of the "batholithic" areas consist of gray gneiss and amphibolite. This estimate is low for the districts visited by the writer. Not only these rocks but also bands of pure limestone are often found near the center of the gneissic areas, where, it would seem, by Adams' theory, that the pure gneiss of the intruding batholith should be found.

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[1] *Igneous Rocks and Their Origin* (1914), 202.

This fact makes it easy to believe that the granite was intruded along planes of slight resistance, and that the limestone terrane of the Grenville series became an immense steam pack, at the time of the intrusion of the granite, with layers of gases followed by fluid granite alternating with layers of limestone. The pre-Cambrian granites were probably accompanied by an immense amount of pneumatolytic gases. The loss of these gases at higher levels due to decreasing pressures accounts for the gradual lessening of the interaction of granite and limestone away from the main granite mass, while within the gneissic areas the retention of the gases allowed the granite to effect a complete change of the limestone to gray gneiss and amphibolite. At certain places the granite failed to penetrate great lenses of the limestone. The gases from layers of fluid magma at the top and bottom of these lenses metamorphosed their borders but failed to affect their centers. Lenses of pure limestone were, therefore, preserved in the midst of gray gneiss and amphibolite.

It has been inferred that the intrusion of the granite occurred along planes of weakness. These, as the structure now shows, were parallel to the stratification of the limestones. Daly and Dawson have stated that in the Shuswap area these planes were due to static metamorphism. Fissility produced in this way would be less apparent in limestones than in the quartzose rocks of British Columbia. However, the fact that the gneissic structure of the Laurentian gneiss is parallel to the stratification of the Grenville series would favor the view that the granite solidified under conditions of stress similar to those which produced the parting planes along which it was intruded. A vertical dike near Baptiste Lake, west of Bancroft, Ontario, shows horizontal schistose structure similar to certain dikes described by Daly[1] in the Shuswap area. Adams and Barlow[2] ascribed the gneissic structure of the Laurentian gneisses to the pressure of intrusion of the granite magma. This, however, would not explain a phenomenon such as that shown by the dike just described (Fig. 2). It is believed that the fissility which allowed the granite to intrude the sediments and the gneissic structure of these granites were both results of a persistent force, the static pressure of the overlying sediments. The Grenville series is said by Adams and Barlow to be approximately 50,000 feet thick. This series compares with the Shuswap Terrane which is 30,000 feet thick.

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[1] Cf. to figure in *Guide Book No. 8*, Part II, Internat. Geol. Cong., Can (1913), 130.

[2] *Can. Geol. Surv., Memoir No. 6* (1910), 78–81.

The elongation or compression of the amphibolitic layers and the presence of amphibolitic inclusions may be explained as easily by the theory of Daly and Fenner as by that of Adams. The granitic gases and fluids must have had their origin at certain definite points. At these points they were pushed upward and sideways along planes of easy parting and a pine-tree structure was produced. In general, the increase of material due to the addition of granite would produce a doming at the center of intrusion with quaquaversal dips away from these points. However, the subsidence of the magma on cooling might very possibly cause a collapse of the dome and irregular dips would result.

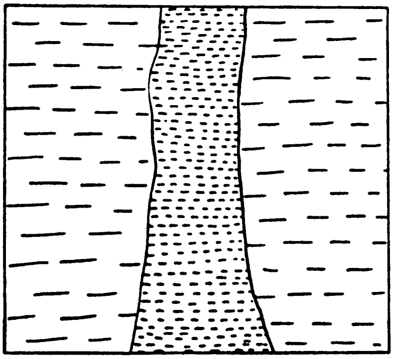
FIG. 2.—A vertical dike showing horizontal schistose structure.

The mechanism of lit-par-lit intrusion, as explained by Fenner,[1] is dependent on the fluxing power of the pneumatolytic gases given off by the granite. These go before and prepare the way for the later intrusion of the granite magma. The prevalence of lit-par-lit rather than batholithic intrusions in pre-Cambrian terranes may be due, therefore, to the greater abundance of magmatic gases in the earlier periods of the earth's history. The vast amounts of pegmatitic granite associated with pre-Cambrian areas lends support to this theory.

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[1] *Journal of Geology*, XXII (1914), pp. 594 ff.

The facts presented above do not mean that cross-cutting bodies are lacking in the Haliburton-Bancroft areas. They are found but are by no means as common as concordant injections.

It seems fair to conclude, therefore: (1) that the so-called "batholiths" were formed by the concordant injection of granite into a fissile limestone terrane; (2) that this fissility was produced by the pressure of the overlying sediments; (3) that the layers of limestones, lying between layers of molten granite, were permeated by the pneumatolytic gases and fluids given off by the granite and transformed to amphibolites or gray gneisses; (4) that the concordant injection of the granite produced the dome-like character of the "gneissic" areas; (5) that the term "batholithic" does not describe the true character of these areas and the term "stromatolithic"[1] is suggested in its place (Fig. 3).

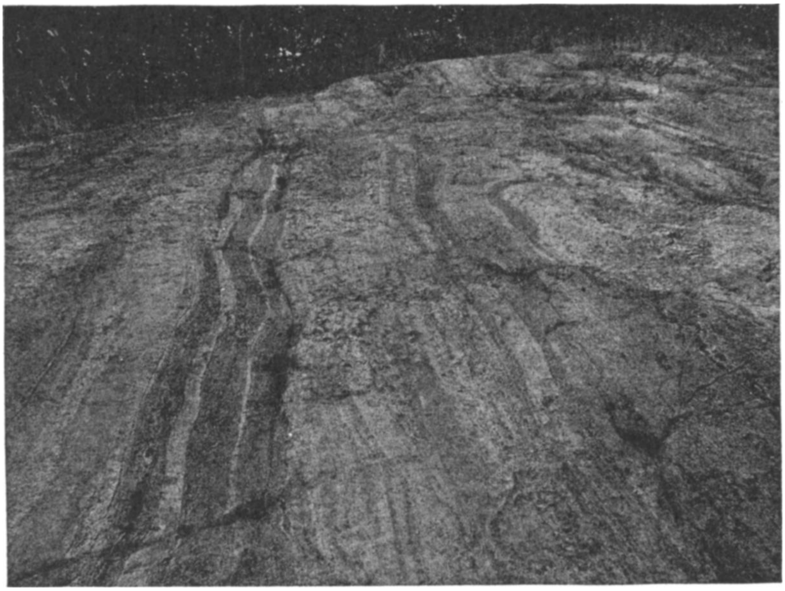

FIG. 3. "Stromatolithic" structure (C. N. Fenner, *Jour. Geol.*, XXII [1914], p. 596).

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[1] From Greek στρωμα, "a layer," and λιθος, "a stone." The noun "Stromatolith" may be defined as a rock mass consisting of many alternating layers of igneous and sedimentary rocks in sill relationship.